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*GROWTH AND DURATION OF LIFE OF CHITON TUBERCULATUS*¹

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Communicated by E. L. Mark, September 30, 1918

The common chiton of the Bermuda Islands, *C. tuberculatus* L., passes all of its post-larval and adult life within the limits of the tidal zone. A thoroughly representative sample of the total chiton population is therefore obtainable, though with difficulty in some places. In certain specific locations it has been possible to study practically all of the chitons there existing. Individuals are of various sizes, ranging during the spring months from 0.6 to 10 cm. in length. The frequency distribution of the lengths of the chitons at each locality is of an obviously multimodal character. It seemed likely, then, that one could work out some of the main features of the growth and duration of life of this mollusk. Facts of this sort, of which in the natural history of marine invertebrates there is a conspicuous deficiency, are not only important in a purely biological way, but have also a bearing upon the problem of estimating in outline the general fertility of the sea. This paper embodies a preliminary report upon one phase of an investigation having to do with the ethology of the chitons, especially from the standpoint of analyzing their behavior under natural conditions.² In a subsequent paper it will be shown that the growth phenomena in chiton probably afford a basis for the consideration of important questions which it has been impossible to approach successfully in such growth-studies as have previously been made on some other organisms in the warmer seas (e.g., Madreporarians). In this paper data are summarized establishing mean growth-curves for chitons inhabiting the region of Great Sound, Bermuda; although the chiton environments comprised within this region, a semi-enclosed sound, are ethologically far from being of a strictly homogeneous type, they nevertheless agree in certain significant physical respects, wherein they differ from other classes of situations (e.g., shores washed by the ocean surf) where chitons of this species also live.

Each of the eight plates which make up the 'shell' of chiton is compounded of a superficial 'tegumentum,' containing sensory receptors (photoreceptors²), and of a more deeply situated 'articulamentum.' The central area of the tegumentum of each plate is marked by a series of more or less distinct transverse grooves, or 'growth-lines.' The number of these growth-lines, best counted upon the six intermediate plates, is constant upon the different plates of one individual. On the assumption that these growth-lines, analogous to the concentric markings of the scales and otoliths of teleosts,³ are formed at the rate of one per year, it is possible to estimate the growth-rate of chiton. The probable correctness of this assumption is assured, (1) by the inspection, throughout the year, of the growth of the young chitons appearing after the

close of the breeding season; (2) by the direct observation that a growth-line is formed during the winter period, and (3) by the coincidence of the findings based upon the counts of growth-lines with those derived from the modes in the frequency-distribution of sizes in the chiton population.

The shell-plates are eroded at a characteristic rate, depending upon the particular environment, the erosion tending to obliterate the growth-lines. This difficulty in making the counts can, however, be overcome, and the measurement of the rate of the erosion itself affords an additional check upon the estimations.

From the region of Great Sound 1090 chitons were examined; of these the ages of 881 (including 476 mature males and 352 females) were determined from the shell-markings. The growth-curve (A) in figure 1 was constructed

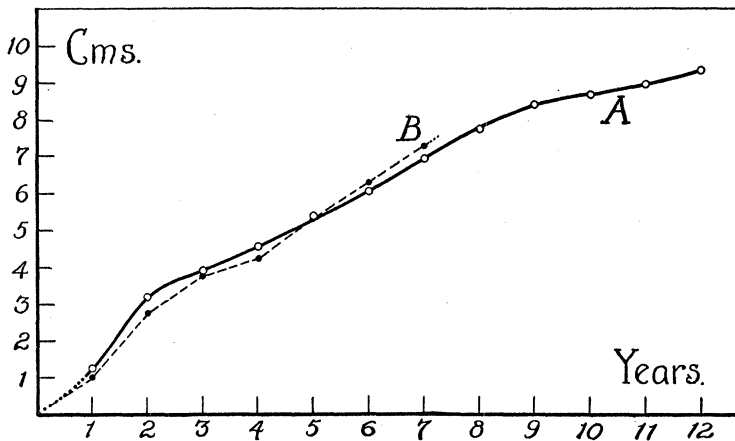


FIG. 1

FIG. 1. A, The modal lengths of *Chiton tuberculatus* at estimated ages one to twelve years; B, the growth of a chiton seven years old, as calculated from its shell markings. Great Sound, Bermuda.

from the modes of the lengths in the respective age classes. These modes were closely coincident with the associated means. The data are heterogeneous to the extent that chitons from different situations within Great Sound have been lumped together. The mean growth-curve for either sex is sensibly the same. The form of the mean growth-curve—exhibiting an initial increase in growth-rate followed by the appearance of several overlapping ‘cycles’ of growth (Robertson)—is similar to that which may be calculated from the markings upon the shell of a single individual (fig. 1, B).

The temporary depression in the rate of growth which commences with the third year is coincident with the onset of sexual maturity. This agrees with the similar correlation to be inferred from some brief statements by Heath⁴ concerning the growth of several other genera of chitons.

It is of interest to determine the duration of life of chiton in different localities. In figure 2 are plotted the percentage frequency of the ages observed for chitons of both sexes. Chitons less than four years old are difficult to obtain in large quantities, because they live in crevices which are in many cases practically inaccessible. Therefore it is legitimate to consider only those individuals which are estimated to be more than five years old. Beyond this age, *C. tuberculatus* tends more and more strongly to come out into exposed situations. Therefore the relative proportions of the age-frequencies observed beyond the six to seven year-class are probably very nearly correct. Defining the 'mean death point' as the age at which there are already dead 50% of

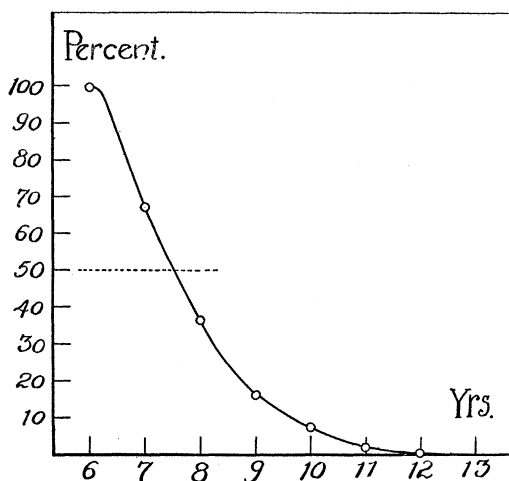


FIG. 2. THE PERCENTAGE SURVIVAL OF CHITONS AFTER THEIR SIXTH YEAR

Based upon records of 516 individuals six years old or over according to the indications of the shell markings. The 'mean death-point' is defined as that age at which 50% still survive; for this locality it falls in the eighth year.

those chitons found to attain the age at which dying-off begins, it is seen (fig. 2) that the natural termination of life comes on the average during the eighth year. This agrees, in general, with the estimated average age of shells found naturally dead.

The growth-curve established for the region of Great Sound, Bermuda, may be used as a norm with which to compare the growth of *Chiton tuberculatus* in other localities. These observations might with advantage be extended to more southerly portions of the West Indian faunal region, where *Chiton tuberculatus* is also found.

Summary.—A curve of the growth of *Chiton tuberculatus* has been obtained for the population in one locality at Bermuda, on the assumption that the age of a chiton may be estimated from the growth-lines upon its shell.

The mean duration of life is probably a little less than eight years. This curve affords a basis for comparing the growth of chitons in differing environments.

¹ Contributions from the Bermuda Biological Station for Research, No. 96.

² Cf. Crozier, W. J., *Amer. Nat.*, *New York*, (in press), and Arey, L. B., and Crozier, W. J., (in press), for an account of observations forming the starting point of these investigations.

³ Winge, Ö., *Medd. Komm. Havunders.*, *Fisk.*, *Kobenhavn*, 4, No. 8, 1915.

⁴ Heath, H., *Zool. Anz.*, *Leipzig*, 29, 1905, (390-393).

GROWTH OF *CHITON TUBERCULATUS* IN DIFFERENT ENVIRONMENTS¹

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In the preceding paper a mean growth-curve for the chiton population of Great Sound, Bermuda, was derived from the examination of 1090 individuals, on the assumption, supported by collateral evidence, that the age of a chiton may be estimated from the markings upon its shell-plates. It was pointed out that curves of this kind might be used to study variations in the growth of *Chiton tuberculatus* in differing environments. A test of this suggestion is afforded by the comparison of the rates of growth and of the average duration of life of this species when living (1) in Great Sound, (2) on the south shore of Bermuda.

Even within the limits of Great Sound itself the chitons inhabiting the shores of the several islands may exhibit differing rates of growth, as indicated in figure 1. When two such islands as Long Island and Grace's Island are compared, it is found that the chitons from the former place grow somewhat less rapidly than do those from the latter, although the initial growth-rates are identical. Most of the Long Island chitons occur on the north shore of that island, which is a cliffed shore with many caves, sheltered from the sun but exposed to the beating of the sea during northwest winter gales. Grace's Island is more sheltered from storms.

On the other hand, chitons from an exposed beach on the south shore of Bermuda, such as that at Cross Bay, which supports a more numerous chiton population than do situations within the stiller waters of the Sound, grow at first more rapidly, but after the first year are smaller, as compared with those living in Great Sound.

The physical differences between two such environments as those presented by Long Island and by the beach at Cross Bay, include at least the following: the sea-water on the south shore is more alkaline, contains more oxygen, and is lower in temperature; the algal food for the chitons is not only specifically